Army Research Laboratory

The Effects of Workload Presented via Visual and Auditory Displays on Soldier Shooting and Secondary Task Performance

by David R. Scribner, Patrick H. Wiley, William H. Harper, and Troy D. Kelley

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14. ABSTRACT
The dismounted warrior will be enabled with dominant situational understanding. The information that a Soldier needs will be provided through a wearable command, control, communication, computing, and intelligence system that will provide enhanced communication, navigation, weapon-sensor connectivity, and other data access features. If such a system is not designed to allow optimal Soldier-system performance, then it is conceivable that the mental overburden could result in decreased Soldier survivability and lethality. This study was performed in the dismounted infantry survivability and lethality test bed shooting simulator facility of the U.S. Army Research Laboratory. The present study proposed the examination of the presentation of mental workload via a single auditory and four visual display conditions: 1) a forearm-mounted personal data assistant display (FMD), 2) a helmet-mounted display (HMD), 3) an FMD with an auditory alert cue, and 4) an HMD with an auditory alert cue. The auditory alert cue informed the Soldier that a new piece of information appeared on his screen. There was also a no-workload shooting condition. Soldiers were asked to complete arithmetic problems while shooting a friend-or-foe scenario. Additionally, the study examined the ability of Soldiers or Marines to maintain the primary task of shooting pop-up friend-or-foe scenarios while performing secondary tasks of mathematical problem solving and situational awareness (SA) memory recall tasks. Finally, the study examined the effect of cognitive workload levels upon the ability of Soldiers to correctly make shoot/do-not-shoot decisions in a friend-or-foe target environment. Participants were 12 U.S. Army Soldiers. They were all military occupational specialty 11B (infantry) with ages ranging from 20 to 27 years old and a mean age of 24.6 years. The shooting task consisted of a 24-target pop-up scenario that used 50% friendly (brown target) and 50% enemy (black target) E-type silhouette targets. Ranges consisted of 75-, 100-, 150-, 200-, 250-, and 300-meter targets. All target presentations were randomized for each 2-minute shooting trial. Target exposure time was 3 seconds. Soldiers were in a foxhole-supported kneeling position for all trials. The M16A2 with iron sights was used. Dependent variables included (primary task) shooting performance (enemy targets hit, errors) and secondary task (math) completion rates, subjective workload assessment technique workload ratings, and subjective rating of events general stress ratings. Subjects were instructed to maintain primary task (shooting) performance through all trials. An analysis of variance analyses revealed significant differences for shooting performance and math task completion rates for certain display configurations.

15. SUBJECT TERMS
dismounted warrior; displays; secondary task; shooting performance

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1. Introduction

One of the U.S. Army's challenges for the dismounted Soldier is to optimize Soldier combat performance with consideration given to the impact of processing additional information. In other words, at what point does additional situational understanding (SU) aid the Soldier's performance and at what point does excess SU information hinder Soldier performance? The purpose of this study was to examine the effects of various displays for shooting task and secondary task performance advantages.

The Army vision statement for future force capability states that U.S. forces will achieve over-matching combat power by employing information to enhance maneuver, firepower, protection, and leadership. This enhancement is enabled by timely and accurate SU.

Interface design solutions are being sought for information systems that enhance SU and decision cycle time performance. The results of this report may provide researchers in the Department of Defense, academia, and industry with information regarding the efficacy and design of information systems for dismounted infantry Soldiers.

This study attempted to discern performance and preference differences between various display types worn by Soldiers while they were shooting. Various displays will be used to provide secondary task information while the Soldier is engaged in a shoot/do-not-shoot friend-or-foe target scenario.

1.1 Command, Control, Communication, Computing, and Intelligence (C4I) Systems

The Project Manager (PM) Soldier and PM Future Force Warrior have made significant progress in solving technical issues for bringing information to the Soldier. The workload and attentional demands, however, of using such systems in complex, multi-task environments are not fully understood. Failure to understand the impact of new weapons and communications systems may bring failure in terms of Soldier information processing ability, task performance, and lethality, if not designed with the Soldier's capabilities, limits, and needs in mind.

These future wearable systems will provide 1) enhanced communication (squad radio and intra-squad communications), 2) enhanced navigation features, 3) weapon-sensor connectivity (to allow viewing of targets indirectly), and 4) other data access such as military occupational specialty (MOS)-related data or emergency medical information.

These information-bearing systems will change the face of the infantryman's job, and there are many questions that remain unanswered about these systems.

First, will the Soldier's training or personnel characteristics need to change significantly for him or her to be able to operate the system effectively?

It is conceivable that an infantry Soldier's aptitude and training requirements may increase to operate a new C4I system. This is a costly path and should be minimized through good human factors design. With good design, a system can provide easily assimilated information that allows the Soldier to make informed and timely decisions that weigh heavily in the outcome of a battle. Many war game simulations and first-person shooter computer games have desirable information display characteristics that provide easy-to-understand displays that are pertinent to the current situation.

Second, will the system affect the Soldier's battlefield effectiveness?

Many studies have shown that the effect of increased workload beyond a certain level can cause some decrement in performance. Humans have limited attentional resources. Systems must be designed so that critical information can be attended to quickly when needed and non-critical information is not presented. Attentional resources of the war fighter must remain the center of focus for combat tasks that will require high levels of concentration and discrimination in future military environments, especially military operations in urban terrain (MOUT) environments. This is the basic question that this study tries to answer.

1.2 Multi-Tasking During Shooting

Increased cognitive tasking is inevitable and many tasks will be performed simultaneously with shooting tasks. Multi-tasking, in its most demanding and crucial form for the dismounted infantry Soldier, would be a scenario where a Soldier is shooting or being shot at while having to attend to pertinent information. Many tasks can be mixed to formulate the battle demand on a Soldier's attention, but the fire fight is thought to be the most stressful, highest demand scenario. The effect of shooting under cognitive load has been studied to some extent by the U.S. Army Research Laboratory (ARL) in recent years (Scribner & Harper, 2001; Scribner, 2002; Kelley & Scribner, 2003). The primary goal of this research is to demonstrate that when the Soldier is overburdened mentally, the results are decreased survivability and increased lethality. The current study was designed to address the workload issue for different display modalities. These have not been tested to examine the shooting performance and workload experienced by Soldiers.

Visual and auditory displays are often categorized as "secondary" displays when viewed in context of a shooting scenario. Some critics state that a Soldier will reduce his workload instantly by "flipping that helmet-mounted display (HMD) right out of the way during a fire fight". This may be true, but there are many emergency messages, warnings, and changes in rules of engagement that could be communicated to a Soldier via this system just before or during a fire-fight scenario. On the design side, many display designers see both an HMD and a forearm-mounted display (FMD) as viable options for a Soldier to choose from. If an FMD is worn, it will not need to be flipped up out of the way and can be accessed visually while the Soldier is in a shooting scenario.

The dismounted warrior has several basic job elements that are often combined or overlapped to create the real-world scenario of workload for the Soldier. These can be simply summarized by the functions of "plan," "move," "shoot," "communicate," and "make good decisions".

The present study was conducted to examine the ability of the Soldiers to perform a secondary (subsidiary or loading) cognitive task while performing a friend-or-foe shooting discrimination task with various visual and auditory displays. The conditions included repeated audio presentations of previous studies (single digit added to a double digit number with a carry operation on the one's place) on shooting and cognitive workload (Scribner & Harper, 2000, Scribner, 2002). The purpose of this was to compare the data from the live fire studies to this study, which used a simulated shooting task. Additionally, this study provided data to attempt to validate a modeling effort that stemmed from the Scribner 2002 study data.

2. Background

2.1 Attentional Resources

There are limited attentional resources in a human. Systems must be designed so that critical information can be attended to when needed and so that non-critical information is not presented. Attentional resources of the war fighter must remain the center of focus for combat tasks that will require high levels of concentration and discrimination.

One basic qualitative model of attentional resources as proposed by Wickens (1984) is illustrated in figure 1.

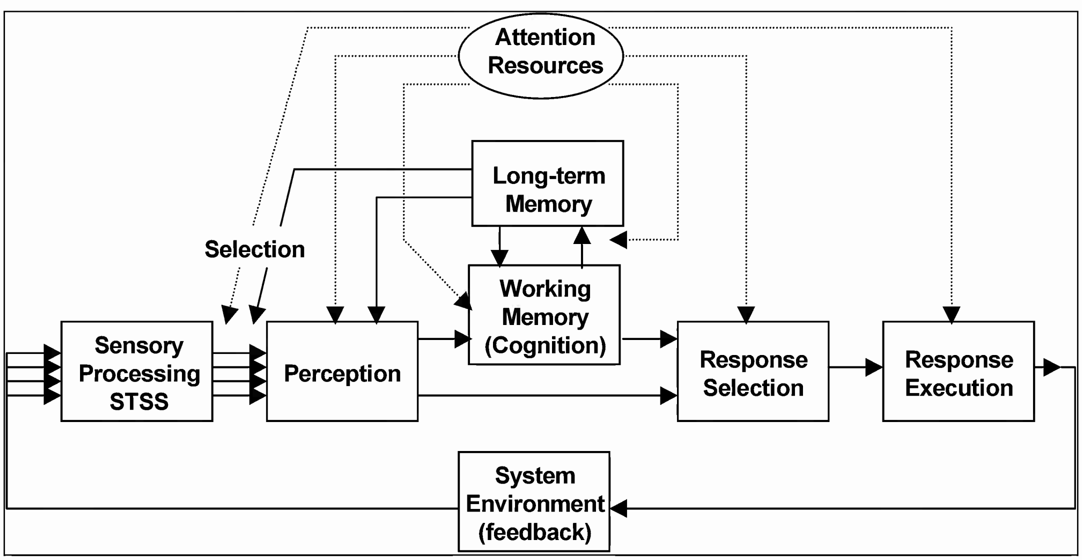

Figure 1. Model of attentional resources (Wickens, 1984).

2.2 Models of Attentional Resources

Several theoretical models currently exist to describe the nature of human multiple task performance. The single-channel hypothesis (Telford, 1931; Welford, 1952) contended that when a person uses mental processes for one task, the processes for another task must wait or be "put on hold" so that the original task can be performed. Kahneman (1973) stated predictions of the human attentional resource. His proposal was that there was a single undifferentiated pool of such resources. The postponement of required mental processes accounted for measured decrements in performance under heavy workload (Gopher, 1993). Early experiments by Allport (1980) and Allport, Antonis, and Reynolds (1972) disproved the single resource theory of mental resources by examining performance under an auditory shadowing task combined with the sight reading of music, which showed a significantly higher recall for different-channel than for same-channel messages. Wickens, Sandry, and Vidulich (1983) also disproved the single-resource theory, finding advantages to cross-modal time sharing over intra-modal time sharing in a laboratory tracking experiment and a complex flight simulation.

The multiple-resource theory, first outlined by Navon and Gopher (1979), claims that various disjointed sets of processing resources are used in combination for performing individual tasks. Each set of resources is assumed to have its own set of divisible capacity. If two or more tasks require the same set of resources, the capacity available to the task resources is supposedly allocated in a flexible graded fashion, depending on task requirements.

Wickens (1984) elaborated on these assumptions, suggesting a three-dimensional (3-D) taxonomy of resources based on stages, codes, and modalities of processing. Wickens identified a number of possible resource capacity channels:

- Type of input and output modality (visual verus auditory input, manual versus vocal output)
- Code or representational format used by the operator (linguistic versus spatial code)
- Stage of resource processing (encoding versus central processing).

Wickens also proposed that three factors would impact performance:

- Resource competition of the task(s),
- Amount of each type of resource available to be allocated to the task(s),
- Relative efficiency of the resource allocated to the task(s).

The Wickens model of multiple resources appears to be the "best fit" of models available to describe the underlying processes in the experimental tasks performed in this study. This model was used as the basic model for this effort since future efforts based on these data will be performed in a system that identifies separate processing resources.

2.3 Hypotheses

1. The efficiency of the visual system will yield improved Soldier secondary task performance, workload, and stress ratings over the auditory system. (The separation of workload channels should yield higher primary task performance with the auditory system.)

2. The effect of an auditory cue with visual displays will yield improved Soldier primary and secondary task performance, workload, and stress ratings because of more efficient task switching.

3. The location of the FMD with a moderate visual scan angle but an uncluttered visual field should improve shooting performance, workload, and stress ratings.

2.4 Objectives

1. To determine the effect of dual task workload with the use of various information display modalities on a friend-or-foe shooting discrimination task, secondary task completion, workload ratings, and stress ratings in a shooting task (hypotheses 1, 3a, and 3b).

2. To determine the effect of an auditory cue for visual display information presence on a friend-or-foe shooting discrimination task, secondary task completion, workload ratings, and stress ratings in a shooting task (hypothesis 2).

3. To determine the display preference data of Soldiers.

4. To test the accuracy of past Atomic Components of Thought-Rational (ACT-R) modeling efforts for predicting Soldier shooting performance under workload for friend-or-foe shooting discrimination tasks (error rate).

3. Methods

The primary task in this study is a friend-or-foe discrimination shooting task. The secondary task used in this study was a non-loading or subsidiary task comprised of mathematics addition problems. Subjects were instructed to avoid making errors in the primary task while performing as many of the secondary task problems as possible, after the primary task was accomplished (Knowles, 1963). This subsidiary task is a measure of spare attentional resources while a primary task is being accomplished.

The input and output modes of primary task and secondary tasks are listed in table 1 in terms of Wickens' (1984) multi-dimensional model of multiple-resource theory. The real experimental manipulations lie in the perceptual processing modality since the rest of the characteristics are distinct since far as coding format and output modality are concerned.

It has been argued that secondary task performance under low to moderate workloads is not sensitive enough to reveal significant effects (Kantowitz & Sorkin, 1983), but because of the moderate workload effect of the mathematical addition problems, secondary task analysis appeared to provide sufficient task sensitivity for the primary task of shooting. This "moderate" level of workload, as rated by the subjective workload assessment technique (SWAT) has been highly effective in recent studies by the author.

Table 1. Primary and secondary task properties.

	Input Modality	Code Format	Output Modality
Primary			
Shooting	Visual	Spatial	Manual
Secondary			
Math Tasks (audio)	Auditory	Verbal	Vocal
Math Tasks (visual)	Visual	Verbal	Vocal
Math Tasks (visual with cue)	Visual	Verbal	Vocal
	Auditory (cue)	Non-verbal	None

3.1 Friend-or-Foe Shooting Scenario

A friend-or-foe decision was used in this shooting task to provide a more realistic mental burden to the shooting task (Scribner & Harper, 2001; Scribner, 2002). Twelve of 24 pop-up targets were brown "E-type" silhouettes to identify them as friendly, causing a desired "don't shoot" decision (figure 3, left). Black "E-type" silhouette targets were designated as enemy targets, which were to be fired upon (figure 2, right).

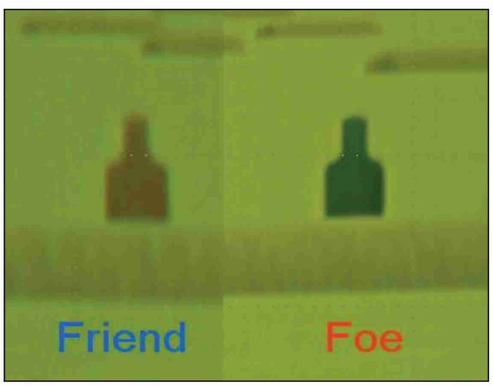

Figure 2. "Friendly" and "enemy" targets.

The shoot/do-not-shoot task was added because of the ever-increasing probability of Soldiers encountering friendly, neutral, or non-combatants in their fighting environment. The targets were all exposed for a duration of 3 seconds and went down if hit before the 3 seconds expired.

3.2 Display Modalities

The different modalities of workload presentation were used to compare likely modes of information display for the Soldier. This involves the presentation of information through auditory via ear buds connected to the FMD, a visual display on the forearm, and an HMD worn over the eye not used for target engagement (figure 3).

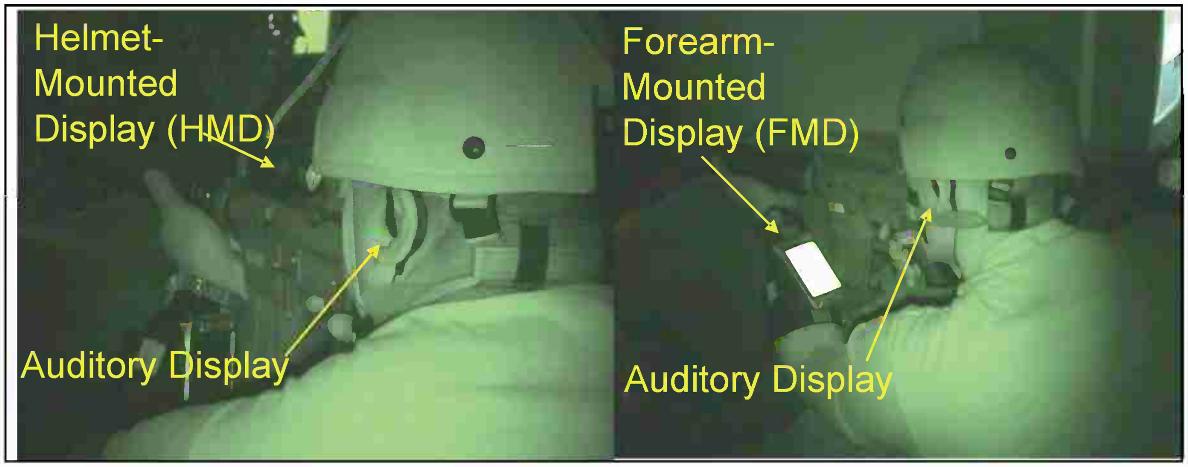

Figure 3. Visual and auditory equipment worn.

3.3 Participants

Participants were 12 male U.S. Army Soldiers, military occupational specialty 11B (dismounted infantryman). All subjects met requirements for 20/30 visual acuity, and all were experienced with the M16A2 and had required minimum weapons qualification.

3.4 Apparatus

3.4.1 Volunteer Agreement Affidavit

A volunteer agreement affidavit (appendix A) was given to each test participant to review before he participated in the study. Upon reading the document, test participants were able to ask all questions concerning their participation in the study. Once they agreed to participate, they signed the document.

3.4.2 Demographic Questionnaire

A demographic questionnaire (appendix B) was administered to collect age, gender, MOS, years in that MOS, and other background information.

3.4.3 Titmus[1] II Vision Testing Device

Subjects were screened for 20/30 both-eye visual acuity far distance with a Titmus II visual testing device. All Soldiers met these criteria.

[1]Titmus is a registered trademark of Titmus Optical.

3.4.4 Dismounted Infantry Survivability and Lethality Test Bed (DISALT)

ARL's Human Research and Engineering Directorate leads the Army's study of shooting performance with small arms systems. The Warrior Performance Research Team of the Dismounted Warrior Branch has a newly acquired small arms shooting simulation facility. This facility is called the DISALT (figure 4).

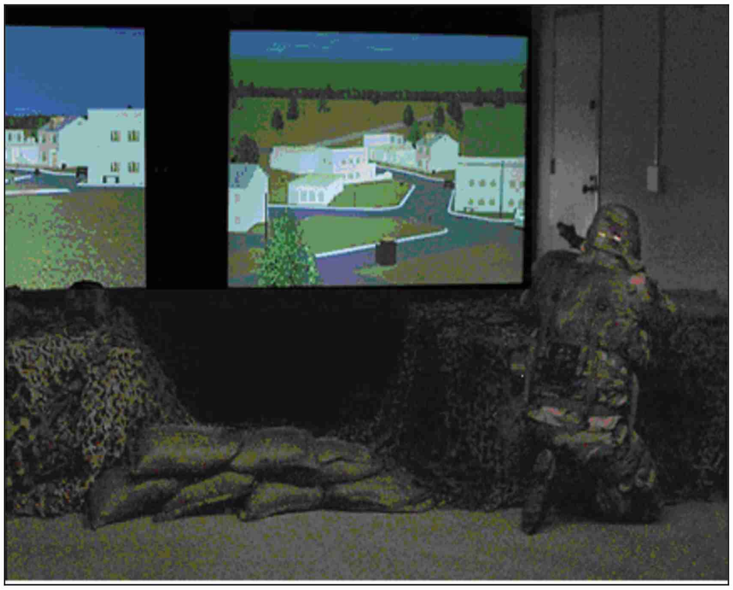

Figure 4. Two-lane DISALT shooting simulator.

The DISALT was originally manufactured to serve as a U.S. Marine Corps marksmanship trainer for ship-borne operations; however, it is highly effective as a research tool for many aspects of scientific research because of its high-fidelity data-capturing capability and flexibility in providing many types of target and 3-D environment shooting scenarios. Customized environments for the simulator were created to include the first experimental environment built for research, the simulated outdoor small-arms experimental range or "M-Range" as it is called locally at Aberdeen Proving Ground (APG) (figure 5).

Figure 5. Live and virtual representations of M range.

3.4.5 Mathematical Problem-Solving Task (secondary)

For all modes, the subject had 2.5 seconds to speak the correct answer or it was scored as an error. Twenty problems were presented to each participant per shooting trial. The problems consisted of adding double-digit and single-digit numbers, always requiring a carrying operation. The number of math problems correctly solved was calculated to score this secondary task.

3.4.6 Secondary Task Display

The first condition for secondary task was "none," in which the participant wore all the equipment turned off, with no secondary task required. The visual conditions consisted of an HMD or an FMD. The FMD was a pocket personal computer mounted with Velcro[2] to the inside of the forearm so that it could be easily seen in a shooting posture. Both visual display modes were presented with or without an auditory warning cue that signaled the presence of a new math problem on the screen. Finally, an auditory condition was also presented via pre-recorded problems from a computer-generated voice.

3.4.7 SWAT

SWAT (Reid, 1988) was used to quantify Soldier workload ratings during various conditions. SWAT has been validated with mathematical processing tasks of various levels for workload assessment. The SWAT form is shown in appendix C. SWAT captures three workload dimensions as well as overall workload:

- Time load is the amount of time pressure that the Soldier experiences in performing the task.
- Mental effort load is the amount of attention and/or concentration required to perform a task.
- Psychological stress load refers to the presence of confusion, frustration, and/or anxiety that hinders the completion of a task.

3.4.8 Subjective Ratings of Events (SRE)

The SRE was used for assessing Soldier global psychological stress. Fatkin, King, and Hudgens (1990) used this scale to aid in the assessment of fire fighter stress levels. The SRE consists of a numerical scale from 0 to 100 to assess a Soldier's stress at a specified point in time. An example of this form is shown in appendix D.

3.4.9 Weapons and Ammunition

Two demilitarized and electronically altered M16A2 rifles with iron sights that accompany the DISALT were used in this study.

[2]Velcro is a registered trademark of Velcro USA, Inc., Manchester, NH.

3.5 Design and Analysis

3.5.1 Independent Variables

The variables manipulated in this study were the displays used to present secondary task (math problems) information to the Soldiers:

- No display (no math problems),
- Auditory presentation of math problems,
- Visual presentation of math problems on an FMD,
- Math problems presented on an FMD with an auditory alert cue for each new problem,
- Visual presentation of math problems on an HMD, and
- Math problems presented on an HMD with an auditory alert cue for each new problem.

3.5.2 Dependent Variables

The data collected consisted of shooting performance (errors or correct judgements of whether to shoot at friendly and enemy targets), secondary task performance (math problem completion), subjective workload and stress data, and Soldier preferences for display type.

The order of target presentation was randomized to preclude any order or learning effects as well. The counter-balanced matrix for condition presentation is provided in appendix E.

4. Procedure and Methodology

The subjects reported to building 459, third floor simulation facility, at APG, to begin study participation. As part of the pre-test procedure, participants were given a volunteer agreement affidavit that described the study and possible risks. They were then screened for visual acuity with a Titmus II vision-testing device. If visual criteria were not met, the subjects were excused from the study. Demographic data were collected, and then the subjects were asked to self-rate present baseline stress levels by using the SRE.

The SWAT technique for measuring workload has two parts: 1) scale development and 2) event scoring. In scale development, a card-sorting exercise is conducted, which is designed to determine the subjective conception of workload for each subject within the three dimensions. During this sorting task, a subject sorts 27 cards that represent all possible combinations of the SWAT dimensions. When the cards are arranged in an order representing which combinations of the dimensions the subject thinks describe the lowest workload to the highest workload combinations, a scale can be created that reflects the way a subject (or a group) perceives the concept of workload. This defines the mathematical model for combining the three elements into a single dimension of subjective mental workload or conjoint analysis.

During event scoring, the subjects rated the experimental conditions using the dimensions of SWAT, one set of ratings for each event. After the events were rated, the workload for each experimental condition was derived. A sample of the event scoring SWAT form is provided in appendix C.

The shooting task consisted of a 24-target pop-up scenario with 50% friendly (brown targets) and 50% enemy (black) E-type silhouette targets. Ranges consisted of 75-, 100-, 150-, 200-, 250-, and 300-meter targets.

Target exposure time was 3 seconds with a 2-second inter-target interval. Soldiers were in a kneeling supported firing position for all trials. De-militarized M16A2 rifles outfitted with electronic switches for the firing selector and trigger with iron sights were used for this study.

The secondary task stimuli (math problems) were presented on one of two visual displays: an FMD or an HMD. These problems were presented in one of five modes in all: 1) aural, 2) visual only with the FMD, 3) visual only with the HMD, or 4) visual with an auditory cue with the FMD, and 5) visual with an auditory cue with the HMD. In the aural mode, each math problem presented consisted of a spoken math problem, followed immediately by a brief response cue tone, indicating that the test participant had permission to respond. The auditory mode employed the use of ear "buds" that fit into the ear canal. Experimenters wore ear buds connected to the same device in all conditions so that they could hear the problem being presented and the response for data verification. Volume levels were adjustable so that the test participant could hear the spoken messages at a comfortable volume. There was a sixth condition in which no workload was presented during the shooting trial.

For visual modes, the entire math problem was presented on an FMD or HMD for time equal to that required for the spoken math problem in the aural mode. The visual with auditory cue mode was identical to the visual-only mode with the addition of a brief presentation cue tone that indicated that a math problem had been presented on the visual display. In all visual modes, response cue tones were presented to signal the start of the response interval. Ear buds and helmets, with HMDs mounted (but flipped up, out of the way when not used) were worn in all trials to maintain similarity in all trials for equipment worn.

All Soldiers were trained by shooting three, 18-target pop-up scenarios, in which all targets were fired upon. The Soldiers then watched one 24-target friend-or-foe pop-up scenario where friendly targets were not to be fired upon. They practiced one friend-or-foe shooting trial with no workload stimulus. This gave the subjects familiarity with the shoot/do-not-shoot aspect of the experimental trials. A minimum of six targets hit was required in each of the first three trials. All subjects met training criteria. Following this training, all 11 experimental trials were presented to the Soldier and were counter-balanced to minimize learning and order effects.

Following each trial, each test participant's cognitive workload and stress levels were collected with SWAT and SRE (stress) data forms, respectively. Test participants were then fully de-briefed and given a point of contact for individual performance or results of the study.

5. Results

All data were analyzed with a repeated measures analysis of variance (ANOVA). Tukey's Least Significant Difference (LSD) test was used as a *post hoc* analysis where overall results deemed that further refinement of mean comparisons was necessary. For analytical purposes, several repeated measures ANOVAs were performed to examine the effect of displays against all others. A 2x2 repeated measures ANOVA was used to examine the effects of visual displays and auditory alert cue presence. Additionally, 1x3 ANOVAs were performed to compare the auditory display to visual displays with and without auditory alert cues.

5.1 Visual Display by Cue Comparisons

A series of 2x2 repeated measures ANOVAs was performed for all dependent variables to examine the aspects of visual display-only by cue performance. These data are presented in table 2. The independent variable levels were visual display type (FMD or HMD) by auditory cue (present or not). Total error rate (the sum of friendly fire error and enemy targets not engaged) yielded significant differences for display type ($p < .05$) (figure 6). Friendly fire error rate yielded significant results ($p < .02$) for cue condition (figure 7). The subjective rating of events (subjective stress) was also significant ($p < .05$) (figure 8).

5.2 Auditory Compared to Visual Displays With No Cue

A series of 1x3 repeated measures ANOVAs was performed for all dependent measures. The independent variable levels were visual display type (Auditory, FMD-No Cue, and HMD-No Cue). These data are presented in table 3. Reaction time, shown in figure 9, yielded significant differences for type of display used ($p < .03$). *Post hoc* analyses determined that differences were significant between Auditory and HMD-No Cue conditions. Secondary task completion rate analysis revealed a significant difference ($p = .05$), seen in figure 10. *Post hoc* analyses determined that the auditory condition was significantly lower than the HMD-No Cue condition.

Table 2. ANOVA table visual display by cue conditions.

	Condition	SS	df	MS	F	P
Enemy Hits						
	Visual Display	4.083	1	4.083	1.918	.194
	Error	23.417	11	2.129		
	Cue	.000	1	.000	.000	1.00
	Error	24.5	11	2.227		
	Visual Display x Cue	.0833	1	.0833	.064	.806
	Error	14.417	11	1.311		
Reaction Time						
	Visual Display	.84	1	.84	2.778	.124
	Error	.333	11	.30		
	Cue	.005	1	.005	.785	.394
	Error	.074	11	.007		
	Visual Display x Cue	.001	1	.001	.059	.813
	Error	.152	11	.014		
Secondary Task Completion (Math Problems)						
	Visual Display	17.74	1	17.74	2.63	.13
	Error	74.19	11	6.74		
	Cue	1.756	1	1.75	.31	.58
	Error	62.36	11	5.67		
	Visual Display x Cue	.96	1	.96	.26	.61
	Error	39.60	11	3.60		
Total Error						
	Visual Display	92.59	1	92.59	4.45	**.05**
	Error	228.58	11	20.78		
	Cue	70.89	1	70.89	3.61	.84
	Error	215.56	11	19.59		
	Visual Display x Cue	1.44	1	1.44	.06	.79
	Error	232.92	11	21.17		
Enemy Targets Not Engaged						
	Visual Display	36.16	1	36.16	1.92	.19
	Error	206.88	11	18.80		
	Cue	1.44	1	1.44	.15	.70
	Error	102.72	11	9.33		
	Visual Display x Cue	5.78	1	5.78	.786	.394
	Error	81.01	11	7.36		
Friendly Targets Engaged						
	Visual Display	13.02	1	13.02	2.53	.13
	Error	56.42	11	5.12		
	Cue	52.08	1	52.08	6.60	**.02**
	Error	86.80	11	7.89		
	Visual Display x Cue	13.02	1	13.02	1.57	.23
	Error	91.14	11	8.28		
SWAT						
	Visual Display	1312.86	1	.1312.86	.61	.44
	Error	23484.21	11	2134.92		
	Cue	371.11	1	371.11	.21	.65
	Error	19395.24	11	1763.20		
	Visual Display x Cue	3070.93	1	3070.93	1.73	.21
	Error	19496.48	11	1772.40		
SRE						
	Visual Display	117.75	1	117.75	.50	.49
	Error	2573.45	11	233.95		
	Cue	157.68	1	157.68	4.53	**.05**
	Error	382.60	11	34.78		
	Visual Display x Cue	229.68	1	229.68	1.31	.27
	Error	1925.23	11	175.02		

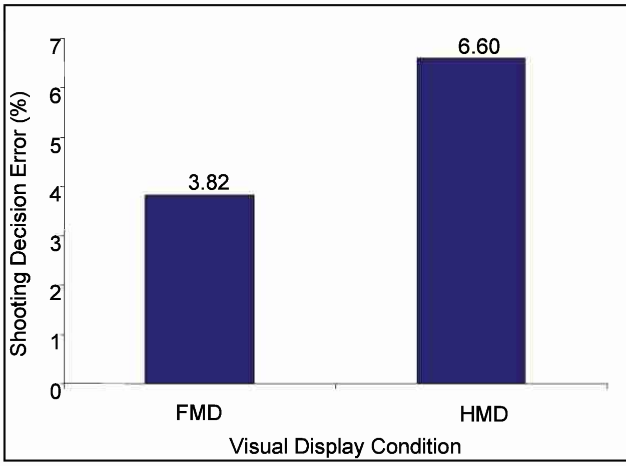

Figure 6. Shooting decision error by visual display.

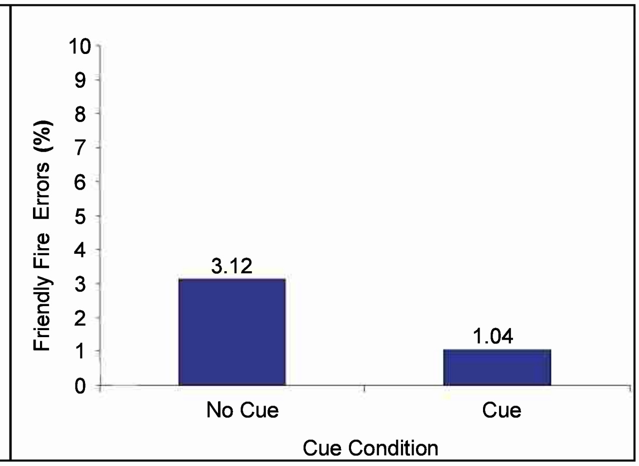

Figure 7. Friendly fire errors by cue.

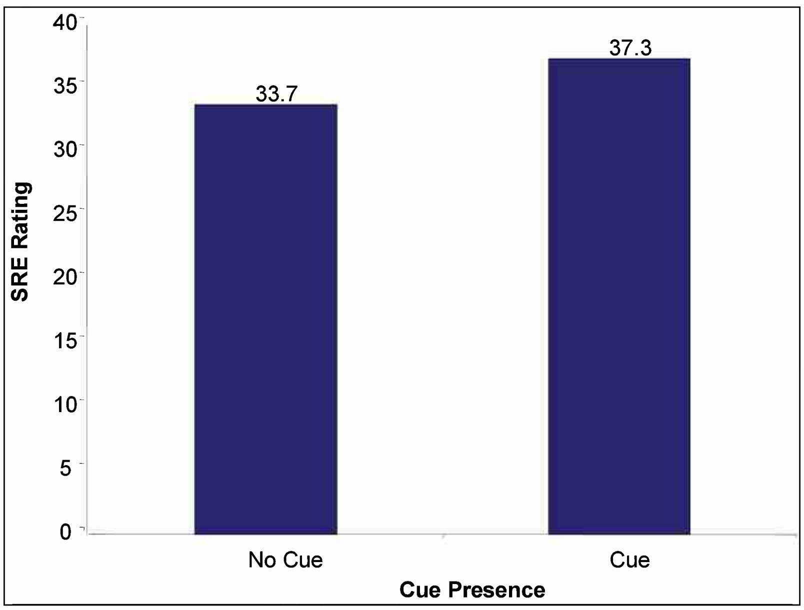

Figure 8. SRE by auditory cue presence.

Table 3. ANOVA table visual display by no cue conditions.

	Condition	SS	df	MS	F	P
Enemy Hits						
	Display	15.72	2	7.86	3.03	.06
	Error	56.94	22	2.58		
Reaction Time						
	Display	.10	2	.05	3.96	**.03**
	Error	.28	22	.01		
Secondary Task Completion (Math Problems)						
	Display	40.38	2	20.19	3.41	**.05**
	Error	130.27	22	5.92		
Total Error						
	Display	99.34	2	49.67	1.91	.17
	Error	571.95	22	25.99		
Enemy Targets Not Engaged						
	Display	15.43	2	7.71	1.25	.30
	Error	135.03	22	6.13		
Friendly Targets Engaged						
	Display	29.90	2	14.95	1.21	.31
	Error	271.02	22	12.31		
SWAT						
	Display	4495.53	2	.2247.76	.86	.43
	Error	57195.80	22	2599.80		
SRE						
	Display	67.78	2	33.89	.22	.79
	Error	3258.65	22	148.12		

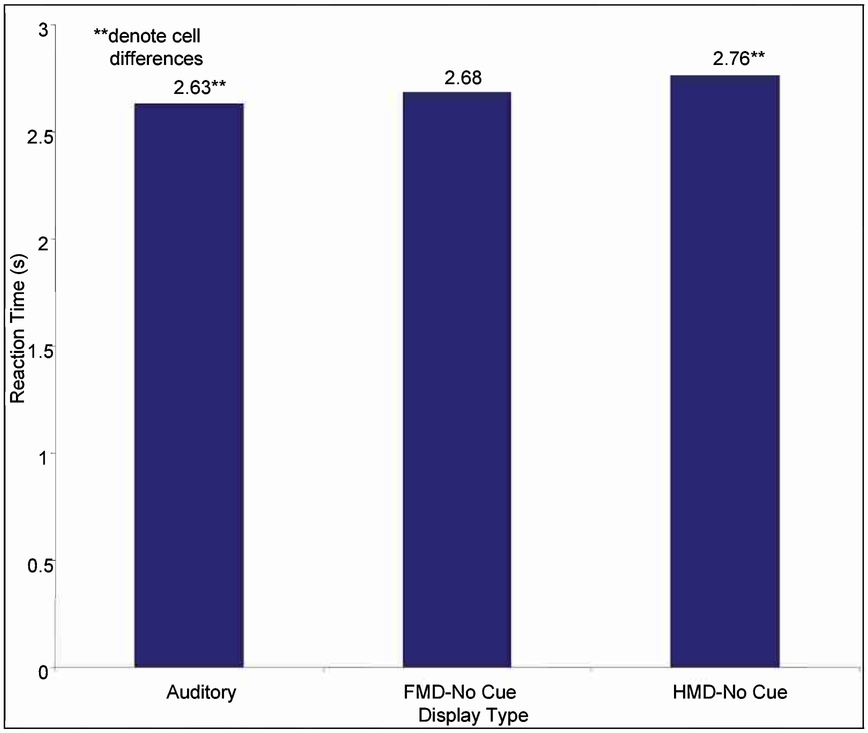

Figure 9. Firing reaction time by display type.

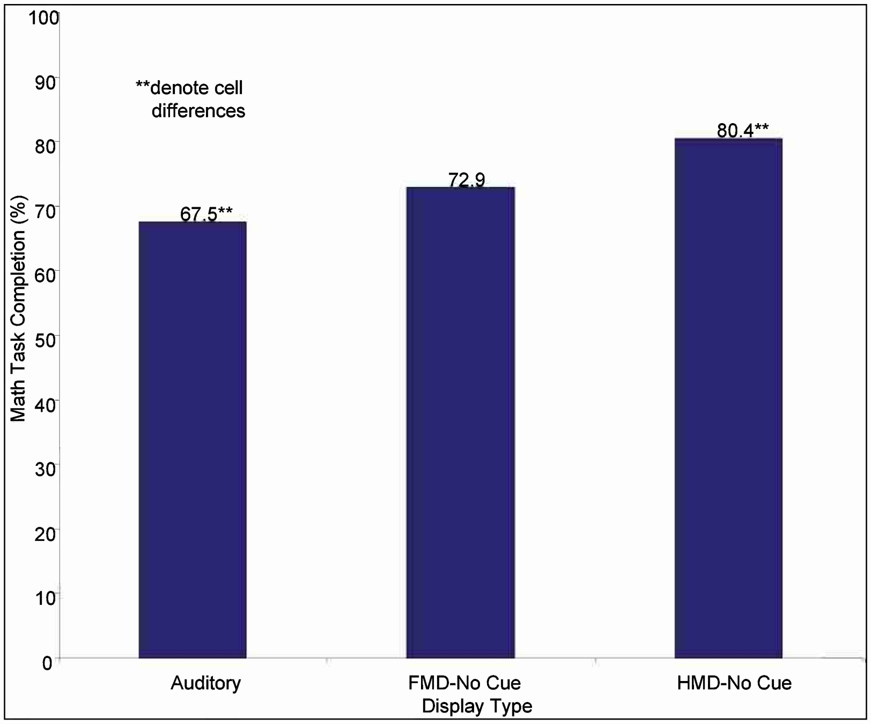

Figure 10. Math problems completed by display type.

5.3 Auditory Compared to Visual Displays With Cue

A series of 1x3 repeated measures ANOVAs was performed for all dependent measures. The independent variable levels were visual display type (Auditory, FMD+Cue, and HMD+Cue). These data are shown in table 4. Enemy hit percentage yielded significant differences for type of display used ($p < .04$). *Post hoc* analyses determined that differences were significant between Auditory and HMD+Cue conditions as seen in figure 11. Single shooting task hit percentage data were added strictly for visual comparison to a baseline shooting task. Secondary task completion rate analysis revealed a significant difference ($p = .05$), as seen in figure 12. *Post hoc* analyses determined that the HMD+Cue was significantly better than the auditory condition.

Table 4. ANOVA table visual display by cue conditions

	Condition	SS	df	MS	F	P
Enemy Hits						
	Display	16.88	2	8.44	3.63	**.04**
	Error	51.11	22	2.32		
Reaction Time						
	Display	.09	2	.04	2.01	.15
	Error	.49	22	.02		
Secondary Task Completion (Math Problems)						
	Display	44.49	2	22.24	3.44	**.05**
	Error	142.25	22	6.46		
Total Error						
	Display	35.68	2	17.84	.79	.46
	Error	496.72	22	22.57		
Enemy Targets Not Engaged						
	Display	47.26	2	23.63	1.73	.20
	Error	299.96	22	13.63		
Friendly Targets Engaged						
	Display	29.90	2	14.95	1.21	.31
	Error	271.02	22	12.31		
SWAT						
	Display	186.13	2	93.06	.57	.56
	Error	3541.14	22	190.96		
SRE						
	Display	344.95	2	172.47	.97	.39
	Error	3891.27	22	176.87		

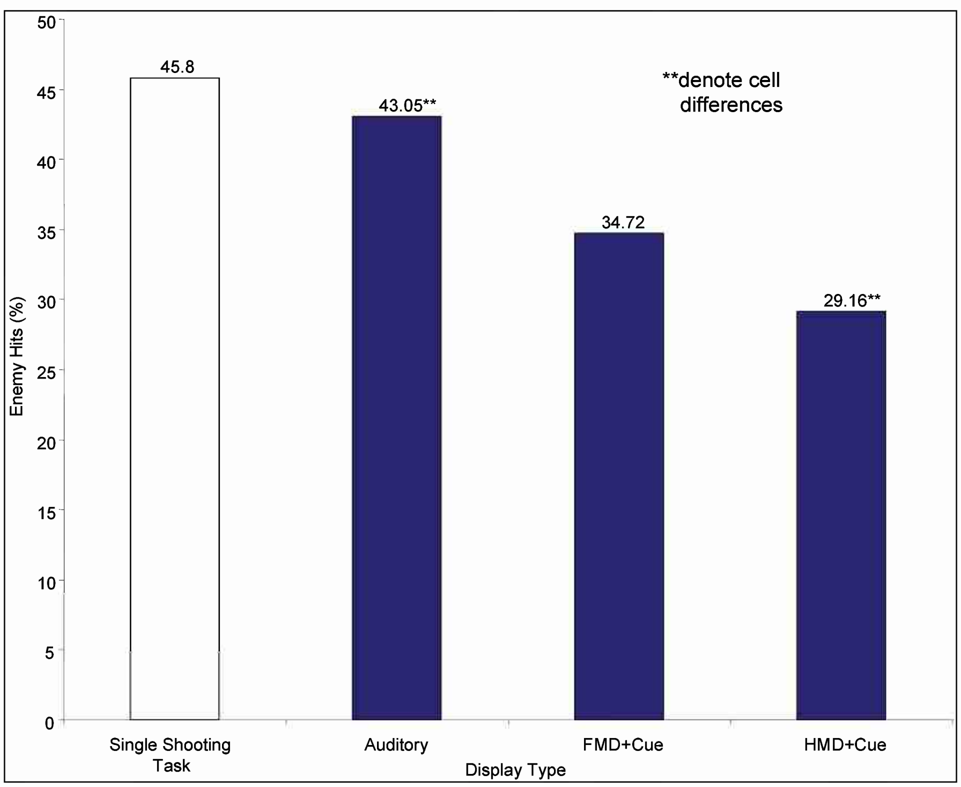

Figure 11. Enemy hits by display type.

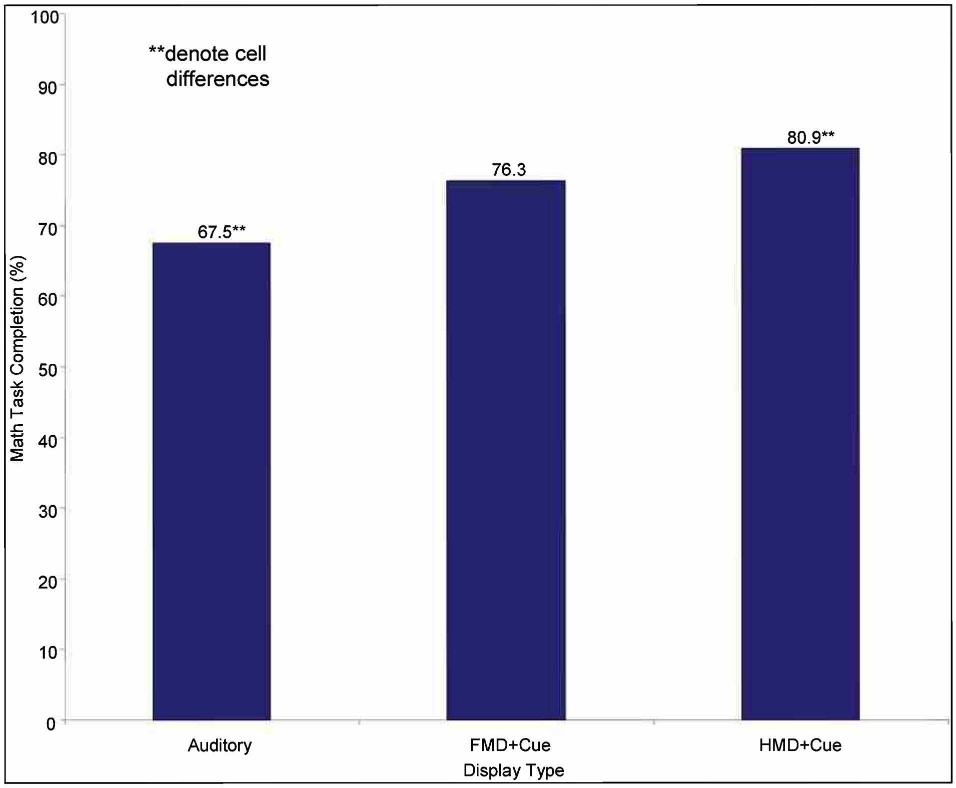

Figure 12. Math problems completed by display type.

5.4 Display Preference

A rank order of all displays is listed in table 5. Soldier preferences for display type used are presented in figures 13.

Table 5. Soldier preferences rank ordering of all five display conditions.

First ranked	FMD with auditory cue
Second ranked	HMD with auditory cue
Third ranked	FMD
Fourth ranked	HMD
Fifth ranked	Audio

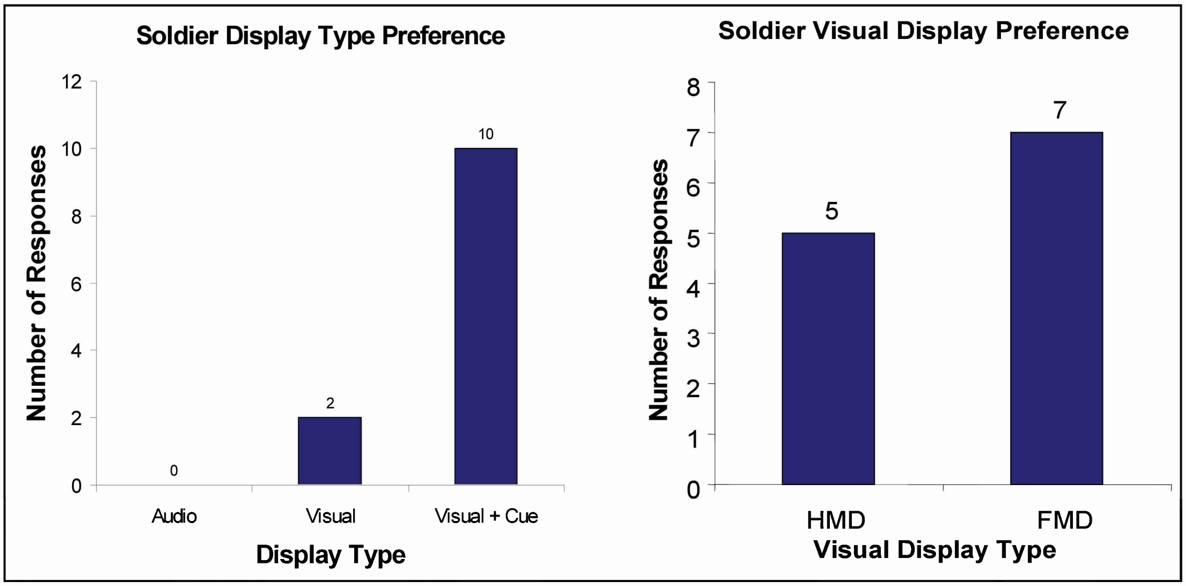

Figure 13. Soldier visual display type preference.

6. Discussion

6.1 SWAT and Stress Ratings

The SWAT data for this simulator study show that shooting is a mentally demanding task that places a burden on the attentional resources of the Soldier. This finding is consistent with a previous live fire data by Scribner and Harper (2001), referenced as study I in table 6. The present study is referenced as study III. The workload as reported by SWAT ratings closely mimic the live fire studies.

Table 6. SWAT and SRE ratings comparisons.

Task	SWAT Rating		SRE Rating	
	Study I	**Study III**	**Study I**	**Study IIII**
Shooting alone	9.6	10.9	11.3	11.5
Shooting plus medium difficulty math task	59.8	60.2	35.4	35.7

These data clearly support the work of Knowles (1963), Kahneman (1973), and Gopher (1993), with the degradation of the two subsidiary secondary tasks that were imposed on subjects. Secondary tasks (math problem completion rates) were supportive of the first hypothesis that the visual system would show clear advantage for Soldier performance. The difference seen in this study for math task completion was a clear increase of 10.4% for visual display over auditory. The task of shooting does have a quantifiable workload, as measured with SWAT.

It appears that for mathematical processing, performance changes from not shooting (single task) to shooting (dual task), have performance differences at about 20% to 23%. Scribner and Harper (2001) study data are shown as study I in table 7.

Table 7. Math task completion rates.

Task	Math task completion rate	
	Study I	Study III
Single task - auditory	82.8	87.3
Dual task - while Soldiers are shooting	60.3	67.5
Attentional resource reduction	22.5%	19.8%
Single task - visual	--	97.7
Dual task - while Soldiers are shooting	--	77.6
Attentional resource reduction	--	20.1%

6.2 Visual Display by Cue Comparisons

The FMD yielded a significantly lower overall error rate (enemy misses and friendly fire shots) as compared to the HMD. There was a reduction from 6.59% to 3.81% in this overall error. It is believed that the non-occlusion of the target scene allowed proper visual attention resources to ascertain the target positions and identification. Additionally, the presence of an auditory cue for visual conditions reduced the rate of friendly fire error from 3.12% to 1.04%.

The subjective stress ratings rose under the presence of an auditory cue; however, this is easily explainable with the arousal factor induced by the cue. The self-reported stress ratings increased from 33.7% to 37.3%.

Overall, the FMD proved to be the best single visual display to choose. The addition of an auditory alert cue provided the extra benefit of reducing fratricide errors.

6.3 Auditory Compared to Visual Displays With No Cue

The auditory condition showed significant speed benefit over the HMD condition in terms of reaction time (2.63 versus 2.76 seconds). The time for Soldiers to take their shot was increased by 4.9% in the HMD condition. On the other hand, the HMD (80.4%) yielded higher secondary task performance (math task completion rate) over the auditory condition (67.5%). This shows that the HMD tend to be a more “distractive” display because of its position in the field of view. The auditory condition tended to be the best condition for maintaining the fastest reaction time for shooting, primary task, while the HMD proved to be the best display for completing secondary task processes.

6.4 Auditory Compared to Visual Displays With Cue

The enemy target hit percentage was significantly higher for the auditory condition (43.05%) as compared to the HMD condition (29.16%). This difference of 13.89% in targets hit highlights the performance hindrance of using an HMD in shooting scenarios. Additionally, the HMD (80.9%) yielded higher secondary task performance (math task completion rate) over the auditory condition (67.5%). This virtually mirrors the data for comparison to visual displays with no cue in section 6.3.

6.5 Soldier Preference Data

The Soldiers favored the FMD with cue by a vast majority. The interesting fact is that when a second display condition was picked, they chose the HMD with cue. This supports the notion that Soldiers found the auditory alert cue quite useful. However, the Soldiers did not perform nearly as well with the HMD with cue as they did with the FMD, which was chosen as the third most popular display type.

The first hypothesis that the visual display systems would be superior in performance for Soldier secondary tasks was supported with the data, specifically, the math task. In general, the 10% difference is directly related to the efficiency and bandwidth of the human visual system. Wickens (1984), Navon and Gopher (1979), Allport, 1980), and Allport et al. (1972) are all supported since the processing of the same information yielded different results for different sensory input modalities. The aspects of Wickens' 3-D taxonomy of resources (specifically the input modality [aural versus visual], stage of resource processing [encoding], and efficiency of the resource allocated to the task) are supported with this study.

The second hypothesis addressing the addition of an auditory alert cue (informing the Soldier that new information has appeared on the display) was also supported with the data from the friendly engagement data. These data showed a significant reduction in the error rate for the visual display with an auditory alert cue.

The third hypothesis (3a) was supported, in part, since the FMD with a cue was not significantly different from the audio condition. This was true in the case of the enemy hit data, reaction time, total errors, and enemy targets not engaged data. The HMD data generally failed to support the third hypothesis (3b) since the HMD conditions yielded significantly poorer performance. Performance suffered with the hit percentage, reaction time, and decision error data.

6.6 Error Predictions

The error prediction modeling effort used data from a previous study (Scribner & Harper, 2001) in order to be able to predict some of the results of the current study. The computational cognitive modeling architecture of the ACT-R was used to model the experimental results. ACT-R is freely available for Government and academic research from Carnegie Mellon University. It is a symbolic production system architecture that is capable of low-level representations of memory structures. ACT-R is implemented in the common Lisp programming language as a collection of Lisp functions and subroutines that can be accessed by the cognitive modeler. Macintosh common Lisp and ACT-R 4.0 running on a G4 Apple Macintosh computer with operating system 9.2 was used. ACT-R had been used previously to predict results from a study that had involved land navigation (Kelley & Scribner, 2003). The goal of the current effort was to use ACT-R to investigate any possible changes in error rates from using visual presentation as input instead of auditory presentation as input. The data provided were used to build an ACT-R framework. The data are shown in figure 14.

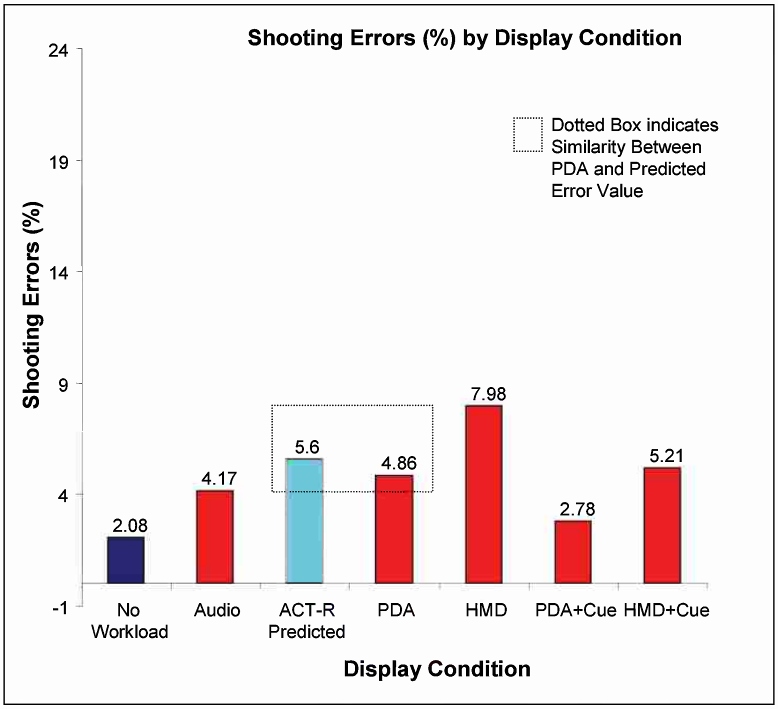

Figure 14. Total errors (from Kelley & Scribner, 2003).

For the visual model, the auditory presentation of the data was removed, and a visual presentation of the data was substituted to simulate the new experimental condition.

The modeled visual condition was modeled as an ideal condition. The data for the model were presented in a format that was distinct and salient from the other visual task of shooting. In other words, there was no overlap between the modeled visual condition of reading the math problems and the modeled visual task of identifying enemy targets. For the actual data, the modeled condition was between both the FMD and HMD conditions, where the math problems were presented on an FMD strapped to the Soldier's arm.

From Kelley and Scribner (2003), it was concluded that "results from this modeling effort indicated that for the primary task of shooting, both a visual secondary task and an auditory secondary task should yield about the same number of errors. This result was generated with a regression equation that incorporated ACT-R activation values as predictor variables for the regression equation. The results are also based on the existing auditory condition error rate data, which were taken from the Scribner and Harper (2001) study." The results of the current study validate the predictions made in the Kelley and Scribner report. The error rate for FMD and HMD conditions were .048 and .079, respectively. The predicted error rate for the visual condition was .056; in other words, the error rate was about the same for both conditions, which the ACT-R model predicted.

7. Conclusions

There are three areas that will affect the quality of how a Soldier in the unit of action will perform his job: 1) improvements in weapons technology, such as the objective individual combat weapon, 2) the increasing probability that future operations will be in MOUT scenarios, and 3) the advancement of C4I systems.

The results of this study may aid the Army in developing future dismounted systems that are designed for minimum cognitive disruption. The future dismounted Soldier must respond efficiently and effectively to single and multiple hostile target scenarios on the battlefield while maintaining cognizance of several aspects of situational awareness (SA). These aspects of SA could be friendly and enemy positions, enemy movement or intentions, and friendly unit movement or intentions, to name a few.

It is argued that future dismounted warrior systems be designed to provide minimal input, output, and central processing resource overlap (Wickens, 1984). It is further suggested that systems provide information to Soldiers in a way that minimizes the requirement for time sharing between external tasks such as shooting and internal system tasks.

Cross-modality attention is the attention of resources to more than one sensory modality. In this case, both visual and auditory attention was required. The auditory task tends to suffer more performance degradation in relation to the visual task as found by Massaro and Warner, 1977). Note that auditory information is intrusive and is difficult to shut out, which is why it is used as warning and caution information (Sorkin, 1987, Simpson & Williams, 1980).

Secondary task performance was least favorable under the auditory condition, supporting the data of Massaro and Warner (1977). However, the information in this mode was not simple as most warnings and cautions are and may not have had the same intrusive nature outlined by Sorkin (1987), Simpson and Williams (1980) in this study.

It is foreseeable that future warriors will be in situations where target engagement will be performed simultaneously with a need to attend to changes in current intelligence. Such changes in intelligence could relate to updated information of friendly units, neutrals, or non-combatants in the area of operations or even orders to evacuate because of lethal environmental effects (friendly air or artillery strikes). Information should be categorized and presented appropriately for status (advisories, cautions, and warnings).

Sound human factors design of these systems dictates that Soldier-systems be given appropriate analysis to identify high workload conditions and task flow bottlenecks. Information should be as easy to access and process as possible. When possible, the use of both auditory and visual icons should be explored. When information cannot be presented as an icon, easy-to-understand visual presentation should be used to eliminate lengthy information uptake and processing requirements. Because fratricide is more probable during conditions of high stress and workload, it is imperative that future warrior systems be assessed for workload demand on Soldiers in all operational scenarios.

Displays meant to be used while Soldiers are in a potential shooting scenario should consist of a system that is easily read by Soldiers, which does not clutter the visual field for target scanning. The system should also include an auditory alert cue for critical warnings and cautions. The scenario setup in this study was for rapid uptake of information during critical dual-task situations. The data show that Soldiers perform more of their secondary task with HMDs but at a greater primary task cost (defensive shooting and correct target discrimination).

The trade-offs in this study would logically lead the reader to believe that the FMD with an auditory alert cue is the best possible choice for the trade-off between the primary and secondary tasks. The data contained in this report should assist the system developers of Soldier-borne information systems in their design efforts.

Additionally, when the display is in a primary viewing location, such as the HMD, the auditory alert cue is an added distraction in many cases and should be eliminated unless there is no indication that information has changed on the display (i.e., numbers flashing on and off the screen). Overall, the HMD conditions as a whole yielded lower enemy target hit performance, higher time to first shot reaction times, and lower enemy engagement rates.

The HMD appears to be the best choice for a single task when hands-free convenience is imperative but not when dual-task scenarios such as shooting are expected. This is evidenced by the higher secondary task completion rates for a single task. The FMD and FMD with an auditory cue have been shown to be the better of visual displays for dual task use in this case.

Note that sound human factors engineering design shows that if the information required by the Soldier is simple, requiring only low-bandwidth information, the auditory condition yields superior enemy hit performance over the visual displays. This can be supported by the data in this study. If information to be presented is more complex or requires high-bandwidth displays for maps, navigation or other graphics, a visual display would be required.

The HMD would not be recommended for shooting tasks because of its cluttering effect and the requirement to use a human hand to put it into view if it is needed during an engagement. It is considered a display that is best for use when the primary task is something of a highly complex or visual nature and when self-defense with small arms is not likely.

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Appendix A. Volunteer Agreement Affidavit

VOLUNTEER AGREEMENT AFFIDAVIT:
ARL-HRED Local Adaptation of DA Form 5303-R. For use of this form, see AR 70-25 or AR 40-38

The proponent for this research is:	**U.S. Army Research Laboratory** **Human Research and Engineering Directorate** **Aberdeen Proving Ground, MD 21005**

Authority:	Privacy Act of 1974, 10 U.S.C. 3013, [Subject to the authority, direction, and control of the Secretary of Defense and subject to the provisions of chapter 6 of this title, the Secretary of the Army is responsible for, and has the authority necessary to conduct, all affairs of the Department of the Army, including the following functions: (4) Equipping (including research and development), 44 USC 3101 [The head of each Federal agency shall make and preserve records containing adequate and proper documentation of the organization, functions, policies, decisions, procedures, and essential transactions of the agency and designed to furnish the information necessary to protect the legal and financial rights of the Government and of persons directly affected by the agency's activities]
Principal purpose:	To document voluntary participation in the Research program.
Routine Uses:	The SSN and home address will be used for identification and locating purposes. Information derived from the project will be used for documentation, adjudication of claims, and mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State, and local agencies.
Disclosure:	The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this data collection.

Part A • Volunteer agreement affidavit for subjects in approved Department of Army research projects

Note: Volunteers are authorized medical care for any injury or disease that is the direct result of participating in this project (under the provisions of AR 40-38 and AR 70-25).

Title of Research Project:	The Effect of Visually-Presented Workload Stimuli on Soldier Shooting Performance	
Human Use Protocol Log # Number:	**ARL-20098-03027, Addendum dated 13 Feb 04**	
Principal Investigator:	David Scribner	Phone: 410-278-5983 E-Mail: dscribne@arl.army.mil
Associate Investigator(s)	Patrick Wiley	Phone: 410-278-5994 E-Mail: pwiley@arl.army.mil
	William Harper	Phone: 410-278-5955 E-Mail: bharper@arl.army.mil
Location of Research:	Aberdeen Proving Ground, MD	
Dates of Participation:	20 Feb 04 through 5 Mar 04	

Part B • To be completed by the Principal Investigator

Note: Instruction for elements of the informed consent provided as detailed explanation in accordance with Appendix C, AR 40-38 or AR 70-25.

Purpose of the Research

You are invited to participate in a study designed to evaluate the effects of visually-presented workload stimuli on shooting performance. More specifically, the purpose of this study is to compare shooting performance data for 1) a forearm-mounted display, 2) a head-mounted display, and 3) an auditory display providing addition problems for you to solve while deciding to shoot or not-shoot at friendly and enemy targets. This study will be conducted at the Army Research Laboratory (ARL) – Human Research Engineering Directorate (HRED) M-Range experimental shooting research facility or at a simulation shooting facility, depending on the availability of live-fire rounds for this study.

Procedures

Participation in this study will require a two to three day's visit to the M-range, live-fire facility, or to the simulation shooting facility. On those days, you will be asked to (1) provide written informed consent to participate in the study, (2) be assigned a confidential participant ID number, (3) complete a demographics questionnaire, (4) choose whether or not to provide the principle investigator your ASVAB score, (5) be tested for visual acuity and stereo vision, and (6) shoot 3, 18-target pop-up scenarios for training, and then shoot 12, 24-target pop-up scenarios using friend and foe targets while solving math problems you see on a visual display that you will be either wearing on a helmet or your forearm. You will also be shooting using an auditory presentation of these same math problems. This will require approximately 6 hours per day while 12 soldiers are cycled 2 at-a-time into the shooting range. You may not be eligible to participate in this study if: (1) your visual acuity is less than 20/30 or you have poor depth perception, (2) your medical profile indicates that your health status requires approval by your physician.

Prior to collecting the research data, you will be asked to (1) complete a set of pre-test questionnaires including the Subjective Stress Scale (SRE), and the Subjective Workload Assessment Tool (SWAT), (3) perform twelve shooting-task conditions, each consisting of 24 target presentations (288 total) each over 2 minutes with a minimum 5-minute rest between trials (4) complete two questionnaires (SRE, SWAT) between each shooting-task condition. You will receive a range safety briefing covering hearing protection and safety procedures to be observed while present that the live-fire range in accordance with Standing Operating Procedure, Safety: M-RANGE Weapons Firing, Number 385-H-188.

Following completion of the pre-test questionnaires, you will participate in twelve different shooting-task conditions. Each condition will consist of 24 pop-up target presentations (trials) distributed across various distances, locations at the live-fire range. The target type presentations will be an enemy targets which will consist of equal sized solid green silhouettes. Friendly targets will consist of the solid green silhouette with a gray 6-inch disk at the center-of-mass, or a solid brown silhouette. The target exposure times will all be 3 seconds. Enemy targets are always to be fired upon. Friendly targets are not to be shot at. Your priority in these scenarios is to shoot as best as you can first, then complete as many addition problems as you can second.

Benefits

You will receive no benefits from participating in the project, other than the personal satisfaction of supporting research efforts to better understand factors contributing to mental workload and how such factors influence physiological, cognitive, and behavioral aspects of multi-task performance, especially in the area of research factors that contribute to fratricide.

Risks

Risks associated with this evaluation are minimal and are less than those encountered by soldiers during their normal field training exercises. Standard safety procedures will be followed for simulated weapon use.
Members of the test administration staff will be close to you throughout all evaluation trials to assist you should a problem arise. If you ask to terminate the test, Care will be taken to minimize risks. If the WBGT equals or exceeds

85°F testing will be halted, for live-fire shooting. You will have a break of at least 5 minutes between shooting-task conditions.

Confidentiality

All data and information obtained about you will be considered privileged and held in confidence. Photographic or video images of you taken during this data collection will not be identified with any of your personal information (name, rank, or status). Complete confidentiality cannot be promised, particularly if you are a military service member, because information bearing on your health may be required to be reported to appropriate medical or command authorities. In addition, applicable regulations note the possibility that the U.S. Army Medical Research and Materiel Command (MRMC-RCQ) officials may inspect the records.

Disposition of Volunteer Agreement Affidavit

The Principal Investigator will retain the original signed Volunteer Agreement Affidavit and forward a photocopy of it to the Chair of the Human Use Committee after the data collection. The Principal Investigator will provide a copy of the signed and initialed Affidavit to you.

Obtaining of ASVAB Scores

IF YOU ARE AN ACTIVE DUTY ENLISTED MILITARY VOLUNTEER, we would like to obtain your Armed Services Vocational Aptitude Battery (ASVAB) scores for potential data analysis. The ASVAB scores would be used strictly for research purposes. The results of any such analyses would be presented for the group of participants as a whole; and no names will be used. With your permission, we will obtain these scores by sending a copy of this signed consent form along with your Social Security Number to the Defense Manpower Data Center (DMDC) in Seaside, CA where ASVAB scores may be obtained from their databases in Arlington, VA or Seaside, CA. If you do not wish your ASVAB scores to be released to the principal investigator, you will still be allowed to participate in the research.

If you would like to participate in this research, please sign one of the following statements, and then complete the information requested at the end of this form:

I **DO AUTHORIZE** you to obtain my ASVAB scores. ______________________________
(Your Signature)

I **DO NOT AUTHORIZE** you to obtain my ASVAB scores. ______________________________
(Your Signature)

Contacts for Additional Assistance

If you have questions concerning your rights on research-related injury, or if you have any complaints about your treatment while participating in this research, you can contact:

Chair, Human Use Committee **U.S. Army Research Laboratory** **Human Research and Engineering Directorate** **Aberdeen Proving Ground, MD 21005** **(410) 278-5919 or (DSN) 298-5919**	**OR**	**Office of the Chief Counsel** **U.S. Army Research Laboratory** **2800 Powder Mill Road** **Adelphi, MD 20783-1197** **(301) 394-1070 or (DSN) 290-1070**

I do hereby volunteer to participate in the research project described in this document. I have full capacity to consent and have attained my 18th birthday. The implications of my voluntary participation, duration, and purpose of the research project, the methods and means by which it is to be conducted, and the inconveniences and hazards that may reasonably be expected have been explained to me. I have been given an opportunity to ask questions concerning this research project. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights or project related injury, I may contact the **ARL-HRED Human Use Committee Chairperson at Aberdeen Proving Ground, Maryland, USA by telephone at 410-278-5919 or DSN 298-5919.** I understand that any published data will not reveal my identity. If I choose not to participate, or later wish to withdraw from any portion of it, I may do so without penalty. I understand that military personnel are not subject to punishment under the Uniform Code of Military Justice for choosing not to take part as human volunteers and that no administrative sanctions can be given me for choosing not to participate. I may at any time during the course of the project revoke my consent and withdraw without penalty or loss of benefits. However, I may be required (military volunteer) or requested (civilian volunteer) to undergo certain examinations if, in the opinion of an attending physician, such examinations are necessary for my health and well being.

Printed Name of Volunteer (First, MI., Last)	
Social Security Number (SSN)	***Permanent Address of Volunteer***
Date of Birth (Month, Day, Year)	
Today's Date (Month, Day, Year)	***Signature of Volunteer***
Signature of Administrator	

Appendix B. Demographic Data Form

DEMOGRAPHICS AND EXPERIENCE QUESTIONNAIRE

Subject Number _____________

Age_____ Height ___ ft ___ in Weight _____lbs

Rank______ Date entered military (month)_______ (year)______

Primary MOS______ Secondary MOS______

1. When was the last time you qualified with the M16A2 rifle?

______ Month _____ Year

2. What is your current level of qualification as a rifleman based on the Army's or Marine's standard?

____expert ____sharpshooter ____marksman

3. Do you usually fire a rifle ____left handed or ____right handed? (Check one)

4. Do you use your ____left eye or ____right eye to aim a weapon?

5. Do you wear glasses or contact lenses when you shoot? ___ Yes ___ No (Check one)

6. Do you play video games or computer games?

____Yes ____No

7. How well do you play video games?
____Poor ____Below Average ____Average ____Above Average ____Excellent

INTENTIONALLY LEFT BLANK

Appendix C. SWAT Event Rating Form

SUBJECTIVE WORKLOAD ASSESSMENT TECHNIQUE

SUBJECT ID__________________________ TASK ID____________________________

(Mark an X in one choice for each of the three areas below that best describes what you believe the task workload to be.)

TIME LOAD

1 Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.

2 Occasionally have spare time. Interruptions or overlap among activities occur frequently.

3 Almost never have spare time. Interruptions or overlap among activities are frequent, or occur all the time.

MENTAL EFFORT

1 Very little conscious mental effort or concentration required. Activity is almost automatic requiring little or no attention.

2 Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.

3 Extensive mental effort or concentration are necessary. Very complex activity requiring total attention.

PSYCHOLOGICAL STRESS

1 Little consusion, frustration or anxiety exists and can be easily accommodated.

2 Moderate stress due to confusion frustration or anxiety. Noticeably adds to workload. Significant compensation is required to maintain adequate performance.

3 High to very intense stress due to confusion frustration or anxiety. High to extreme determination and self-control required.

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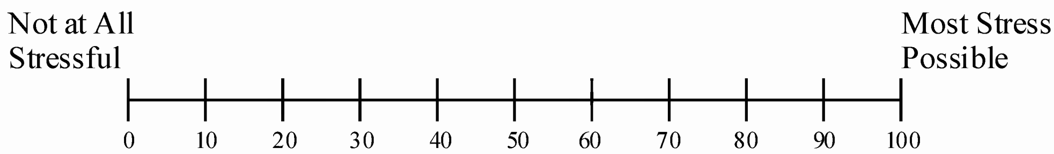
Appendix D. Subjective Rating of Events (SRE) Form

SUBJECT ID: ______________________ TASK ID: ___________________

1. The scale below represents a range of how stressful an event might be. Put an "X" on the line to rate how much stress you experienced <u>during the previous experimental trial?.</u>



2. At what number value does the "X" touch the line? ________

INTENTIONALLY LEFT BLANK

Appendix E. Experimental Condition Presentation Order

Subject	Trial 1	math only	2	math only	3	math only	4	math only	5	math only	6
1	n	a	a	FMD	FMD	hmd	hmd	aFMD	aFMD	ahmd	ahmd
2	a	ahmd	hmd	aFMD	n	hmd	ahmd	FMD	FMD	a	aFMD
3	FMD	aFMD	n	FMD	aFMD	ahmd	a	hmd	ahmd	a	hmd
4	hmd	FMD	ahmd	aFMD	a	a	aFMD	ahmd	n	hmd	FMD
5	aFMD	ahmd	FMD	apds	ahmd	hmd	n	FMD	hmd	a	a
6	ahmd	a	aFMD	FMD	hmd	hmd	FMD	aFMD	a	ahmd	n
7	n	a	a	FMD	FMD	hmd	hmd	aFMD	aFMD	ahmd	ahmd
8	a	ahmd	hmd	aFMD	n	hmd	ahmd	FMD	FMD	a	aFMD
9	FMD	aFMD	n	FMD	aFMD	ahmd	a	hmd	ahmd	a	hmd
10	hmd	FMD	ahmd	aFMD	a	a	aFMD	ahmd	n	hmd	FMD
11	aFMD	ahmd	FMD	apds	ahmd	hmd	n	FMD	hmd	a	a
12	ahmd	a	aFMD	FMD	hmd	hmd	FMD	aFMD	a	ahmd	n

Experimental Trial Presentation Order.

n=no wl + shoot a=auditory workload FMD=visual wl via FMD
hmd=visual wl via hmd aFMD=visual wl via FMD + audio cue ahmd= visual wl via FMD + audio cue

math only indicates that the math addition task was performed alone in that condition.

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